

Claims

1. A mass spectrometer comprising:
 - a first electric field region; and
 - 5 a Time of Flight mass analyser comprising an extraction or acceleration region;wherein in a mode of operation a group of ions having substantially different mass to charge ratios is arranged to pass through said first electric field
- 10 region, wherein a first electric field which varies with time is applied across at least a portion of said first electric field region such that at least some ions having substantially different mass to charge ratios are arranged to arrive at said extraction or acceleration
- 15 region at substantially the same first time.

2. A mass spectrometer as claimed in claim 1, wherein at least 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95% or
- 20 substantially 100% of the ions in said group of ions are arranged to arrive at said extraction or acceleration region at substantially said same first time.

3. A mass spectrometer as claimed in claim 1, wherein
- 25 said group of ions have a range of mass to charge ratios and wherein said range is at least 10, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2500, 3000, 3500,
- 30 4000, 4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 9500 or 10000 mass to charge ratio units.

4. A mass spectrometer as claimed in claim 1, wherein
at least 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%,
50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95% or
substantially 100% of said ions arriving at said
5 extraction or acceleration region at substantially said
same first time are subsequently extracted or
accelerated from said extraction or acceleration region.

5. A mass spectrometer as claimed in claim 1, wherein
10 in use at least some ions having a first mass to charge
ratio enter said first electric field region with a
first initial velocity and exit said first electric
field region with a first final velocity and wherein in
use at least some ions having a second different mass to
15 charge ratio enter said first electric field region with
a second initial velocity and exit said first electric
field region with a second final velocity, wherein said
first initial velocity is greater than said second
initial velocity and said first final velocity is less
20 than said second final velocity.

6. A mass spectrometer as claimed in claim 1, wherein
ions having different mass to charge ratios enter in use
said first electric field region with various initial
25 velocities and exit said first electric field region
with various final velocities, and wherein the ions
having the fastest initial velocities are the ions which
have the slowest final velocities.

30 7. A mass spectrometer as claimed in any claim 1,
wherein ions having different mass to charge ratios
enter in use said first electric field region with
various initial velocities and exit said first electric

field region with various final velocities, and wherein the ions having the slowest initial velocities are the ions which have the fastest final velocities.

5 8. A mass spectrometer as claimed in claim 1, wherein
in use at least some ions having different mass to
charge ratios enter said first electric field region
with a first range of velocities and exit said first
electric field region with a second range of velocities,
10 wherein said second range of velocities is substantially
smaller than said first range of velocities.

9. A mass spectrometer as claimed in claim 1, wherein
ions having a first mass to charge ratio exit said first
15 electric field region before ions having a second mass
to charge ratio, wherein said first mass to charge ratio
is smaller than said second mass to charge ratio.

10. A mass spectrometer as claimed in claim 1, wherein
20 said first electric field causes ions having a first
mass to charge ratio to exit said first electric field
region at a first velocity and ions having a second mass
to charge ratio to exit said first
electric field region at a second velocity.

25 11. A mass spectrometer as claimed in claim 10, wherein
said second mass to charge ratio is greater than said
first mass to charge ratio.

30 12. A mass spectrometer as claimed in claim 10, wherein
said second velocity is greater than said first
velocity.

13. A mass spectrometer as claimed in claim 12, wherein
said second velocity is < 1%, 1-5%, 5-10%, 10-15%, 15-
20%, 20-25%, 25-30%, 30-35%, 35-40%, 40-45%, 45-50%, 50-
55%, 55-60%, 60-65%, 65-70%, 70-75%, 75-80%, 80-85%, 85-
5 90%, 90-95% or 95-100% greater than said first velocity.

14. A mass spectrometer as claimed in claim 12, wherein
said second velocity is 100-200%, 200-300%, 300-400%,
400-500%, 500-600%, 600-700%, 700-800%, 800-900%, 900-
10 1000%, 1000-2000%, 2000-3000%, 3000-4000%, 4000-5000%,
5000-6000%, 6000-7000%, 7000-8000%, 8000-9000%, 9000-
10000% or > 10000% greater than said first velocity.

15. A mass spectrometer as claimed in claim 10, wherein
15 said second velocity is substantially equal to said
first velocity.

16. A mass spectrometer as claimed in claim 1, wherein
in use said first electric field causes undesired ions
20 to arrive at said extraction or acceleration region at a
second different time.

17. A mass spectrometer as claimed in claim 16, wherein
at least some of said undesired ions arriving at said
25 extraction or acceleration region at said second
different time are not subsequently extracted or
accelerated into said extraction or acceleration region.

18. A mass spectrometer as claimed in claim 16, wherein
30 said undesired ions comprise matrix, background or
interference ions.

19. A mass spectrometer as claimed in claim 1, wherein
at least some of said ions having substantially
different mass to charge ratios arriving at said
extraction or acceleration region at substantially said
5 same first time also arrive at substantially the same
position or location within said extraction or
acceleration region at said same first time.

20. A mass spectrometer as claimed in claim 1, wherein
10 said first electric field region is arranged between at
least a first electrode and a second electrode, and
wherein the potential of either said first electrode
and/or said second electrode is varied in use with time.

15 21. A mass spectrometer as claimed in claim 20, wherein
said first electrode comprises one or more tubular
electrodes and/or one or more plate electrodes and/or
one or more grid electrodes.

20 22. A mass spectrometer as claimed in claim 20, wherein
said second electrode comprises one or more tubular
electrodes and/or one or more plate electrodes and/or
one or more grid electrodes.

25 23. A mass spectrometer as claimed in claim 20, wherein
said first electrode and/or said second electrode
comprises: (i) one or more annular electrodes; (ii) one
or more Einzel lens arrangements comprising three or
more electrodes; (iii) one or more segmented rod sets;
30 (iv) one or more quadrupole, hexapole, octapole or
higher order rod sets; or (v) a plurality of electrodes
having apertures through which ions are transmitted in
use.

24. A mass spectrometer as claimed in claim 1, further comprising one or more electrodes arranged within said first electric field region, wherein the potential of at least one of said one or more electrodes is varied in use with time.

25. A mass spectrometer as claimed in claim 24, wherein said one or more electrodes comprises: (i) one or more tubular electrodes; (ii) one or more annular electrodes; (iii) one or more Einzel lens arrangements comprising three or more electrodes; (iv) one or more segmented rod sets; (v) one or more quadrupole, hexapole, octapole or higher order rod sets; or (vi) a plurality of electrodes having apertures through which ions are transmitted in use.

26. A mass spectrometer as claimed in claim 1, wherein the magnitude of said first electric field varies with time whilst ions pass through said first electric field region.

27. A mass spectrometer as claimed in claim 26, wherein the magnitude of said first electric field increases with time.

28. A mass spectrometer as claimed in claim 26, wherein the magnitude of said first electric field decreases with time.

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29. A mass spectrometer as claimed in any of claims 26, wherein the magnitude of said first electric field

varies substantially sinusoidally or cosinusoidally with time.

30. A mass spectrometer as claimed in claim 26, wherein
5 the magnitude of said first electric field varies substantially exponentially with time.

31. A mass spectrometer as claimed in claim 26, wherein
the magnitude of said first electric field varies
10 substantially: (i) linearly with time; (ii) according to a square law ramp function with time; (iii) according to a cubic law ramp function with time; (iv) according to a power law ramp function with time; (v) according to a quadratic or higher order polynomial function with time;
15 or (vi) according to a multiple stepped function with time.

32. A mass spectrometer as claimed in claim 1, wherein
the direction of said first electric field is in a
20 direction substantially parallel to the direction of ion travel.

33. A mass spectrometer as claimed in claim 1, wherein
the direction of said first electric field changes
25 whilst ions pass through said first electric field region.

34. A mass spectrometer as claimed in claim 1, wherein
the length of said first electric field region is
30 selected from the group consisting of: (i) < 1 mm; (ii) 1-2 mm; (iii) 2-3 mm; (iv) 3-4 mm; (v) 4-5 mm; (vi) 5-6 mm; (vii) 6-7 mm; (viii) 7-8 mm; (ix) 8-9 mm; (x) 9-10 mm; and (xi) > 10 mm.

35. A mass spectrometer as claimed in claim 1, wherein
said first electric field acts to decelerate at least
some of said ions passing through said first electric
5 field region.

36. A mass spectrometer as claimed in claim 1, wherein
said first electric field acts to accelerate at least
some of said ions passing through said first electric
10 field region.

37. A mass spectrometer as claimed in claim 1, further
comprising a first field free region arranged downstream
of said first electric field region.

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38. A mass spectrometer as claimed in claim 37, wherein
said first field free region is formed by one or more
tubular electrodes and/or one or more plate electrodes.

20 39. A mass spectrometer as claimed in claim 37, wherein
the length of said first field free region is selected
from the group consisting of (i) ≤ 50 mm; (ii) ≥ 50 mm;
(iii) ≥ 100 mm; (iv) ≥ 150 mm; (v) ≥ 200 mm; (vi) ≥ 250
mm; (vii) ≥ 300 mm; (viii) ≥ 350 mm; (ix) ≥ 400 mm; (x)
25 ≥ 450 mm; and (xi) ≥ 500 mm.

40. A mass spectrometer as claimed in claim 37, further
comprising a collision or fragmentation cell arranged in
said first field free region.

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41. A mass spectrometer as claimed in claim 40, wherein
said collision or fragmentation cell comprises a tubular
housing.

42. A mass spectrometer as claimed in claim 40, wherein ions are not confined radially within said collision or fragmentation cell by pseudo-potential wells.

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43. A mass spectrometer as claimed in claim 40, wherein no AC or RF voltages are applied to said collision or fragmentation cell in order to provide radial confinement of ions.

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44. A mass spectrometer as claimed in claim 40, further comprising an electrostatic energy analyser and/or mass filter and/or ion gate arranged upstream of said collision or fragmentation cell.

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45. A mass spectrometer as claimed in claim 40, further comprising an electrostatic energy analyser and/or mass filter and/or ion gate arranged downstream of said collision or fragmentation cell.

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46. A mass spectrometer as claimed in claim 44, wherein said mass filter comprises a magnetic sector mass filter, an RF quadrupole mass filter or a Wien filter.

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47. A mass spectrometer as claimed in claim 1, further comprising a second electric field region arranged upstream of said first electric field region wherein in use a second electric field is maintained across at least a portion of said second electric field region.

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48. A mass spectrometer as claimed in claim 47, wherein said second electric field remains substantially

constant with time whilst ions pass through said second electric field region.

49. A mass spectrometer as claimed in claim 47, wherein
5 said second electric field causes at least 10%, 20%,
30%, 40%, 50%, 60%, 70%, 80%, 90%, 95% or substantially
100% of ions passing through said second electric field
region to exit said second electric field region with
substantially the same kinetic energy.

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50. A mass spectrometer as claimed in claim 47, wherein
whilst ions pass through said second electric field
region a potential difference is maintained across at
least a portion of said second electric field region
15 selected from the group consisting of: (i) < 50 V; (ii)
50-100 V; (iii) 100-150 V; (iv) 150-200 V; (v) 200-250
V; (vi) 250-300 V; (vii) 300-350 V; (viii) 350-400 V;
(ix) 400-450 V; (x) 450-500 V; (xi) 500-600 V; (xii)
600-700 V; (xiii) 700-800 V; (xiv) 800-900 V; (xv) 900-
20 1000 V; (xvi) 1-2 kV; (xvii) 2-3 kV; (xviii) 3-4 kV;
(xix) 4-5 kV; and (xx) >5 kV.

51. A mass spectrometer as claimed in claim 47, wherein
the length of said second electric field region is
25 selected from the group consisting of (i) < 1mm; (ii) 1-
2 mm; (iii) 2-3 mm; (iv) 3-4 mm; (v) 4-5 mm; (vi) 5-6
mm; (vii) 6-7 mm; (viii) 7-8 mm; (ix) 8-9 mm; (x) 9-10
mm; and (xi) > 10 mm.

30 52. A mass spectrometer as claimed in claim 47, wherein
said second electric field is varied with time whilst
ions pass through said second electric field region.

53. A mass spectrometer as claimed in claim 1, further comprising a second field free region arranged upstream of said first electric field region.

5 54. A mass spectrometer as claimed in claim 47, further comprising a second field free region arranged between said first electric field region and said second electric field region.

10 55. A mass spectrometer as claimed in claim 53, wherein said second field free region is formed by one or more tubular electrodes and/or one or more plate electrodes.

56. A mass spectrometer as claimed in claim 53, wherein
15 at least some of the ions passing through said second field free region become spatially and/or temporally separated according to their mass to charge ratio.

57. A mass spectrometer as claimed in claim 53, wherein
20 the length of said second field free region is selected from the group consisting of (i) < 10mm; (ii) 10-20 mm; (iii) 20-30 mm; (iv) 30-40 mm; (v) 40-50 mm; (vi) 50-60 mm; (vii) 60-70 mm; (viii) 70-80 mm; (ix) 80-90 mm; (x) 90-100 mm; and (xi) > 100 mm.

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58. A mass spectrometer as claimed in claim 1, further comprising an axial DC acceleration lens arranged upstream of said extraction or acceleration region.

30 59. A mass spectrometer as claimed in claim 1, wherein said extraction or acceleration region has a length selected from the group consisting of: (i) < 1 mm; (ii)

1-2 mm; (iii) 2-3 mm; (iv) 3-4 mm; (v) 4-5 mm; (vi) 5-6 mm; (vii) 6-7 mm; (viii) 7-8 mm; (ix) 8-9 mm; (x) 9-10 mm; and (xi) > 10 mm.

5 60. A mass spectrometer as claimed in claim 1, wherein the axial length of said extraction or acceleration region is adjustable.

61. A mass spectrometer as claimed in claim 1, wherein
10 said extraction or acceleration region comprises a plurality of extraction or acceleration electrodes.

62. A mass spectrometer as claimed in claim 61, wherein
15 in use the effective length of said extraction or acceleration region is adjusted by varying the number extraction or acceleration electrodes used to extract or accelerate ions.

63. A mass spectrometer as claimed in claim 1, further
20 comprising an adjustable aperture, shutter or beam stop arranged between an extraction or acceleration electrode arranged in said extraction or acceleration region and a drift or flight region arranged downstream of said extraction or acceleration region, wherein in a mode of
25 operation said adjustable aperture, shutter or beam stop substantially prevents or attenuates at least some ions which have been extracted or accelerated by said extraction or acceleration electrode from being transmitted into said drift or flight region.

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64. A mass spectrometer as claimed in claim 63, wherein the size, area, diameter, length, width or transmission

coefficient of said aperture, shutter or beam stop is adjustable.

65. A mass spectrometer as claimed in claim 63, wherein
5 at least some parent ions are fragmented in use in a
fragmentation or collision cell into fragment ions and
wherein fragment ions and their corresponding parent
ions exit said fragmentation or collision cell with
substantially the same velocity and reach said
10 extraction or acceleration electrode at substantially
the same time.

66. A mass spectrometer as claimed in claim 63, wherein
in said mode of operation multiple parent ions having
15 different mass to charge ratios and their corresponding
fragment ions are extracted or accelerated into said
drift or flight region at the same time and wherein said
adjustable aperture, shutter or beam stop substantially
prevents or attenuates at least some parent ions and
20 their corresponding fragment ions from being transmitted
into said drift or flight region whilst substantially
permitting or transmitting at least some other parent
ions and their corresponding fragment ions into said
drift or flight region.

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67. A mass spectrometer as claimed in claim 1, further
comprising an ion source selected from the group
consisting of: (i) an Electrospray ("ESI") ion source;
(ii) an Atmospheric Pressure Chemical Ionisation
30 ("APCI") ion source; (iii) an Atmospheric Pressure Photo
Ionisation ("APPI") ion source; (iv) a Laser Desorption
Ionisation ("LDI") ion source; (v) an Inductively
Coupled Plasma ("ICP") ion source; (vi) an Electron

Impact ("EI) ion source; (vii) a Chemical Ionisation
("CI") ion source; (viii) a Field Ionisation ("FI") ion
source; (ix) a Fast Atom Bombardment ("FAB") ion source;
(x) a Liquid Secondary Ion Mass Spectrometry ("LSIMS")
5 ion source; (xi) an Atmospheric Pressure Ionisation
("API") ion source; and (xii) a Field Desorption ("FD")
ion source.

68. A mass spectrometer as claimed in claims 1, further
10 comprising a Matrix Assisted Laser Desorption Ionisation
("MALDI") ion source.

69. A mass spectrometer as claimed in claim 1, further
comprising a Desorption/Ionisation on Silicon ("DIOS")
15 ion source.

70. A mass spectrometer as claimed in claim 1, further
comprising a continuous ion source.

20 71. A mass spectrometer as claimed in claim 1, further
comprising a pulsed ion source.

72. A mass spectrometer as claimed in claim 1, wherein
said Time of Flight mass analyser comprises an
25 orthogonal acceleration Time of Flight mass analyser.

73. A mass spectrometer as claimed in claim 1, wherein
said Time of Flight mass analyser comprises an axial
acceleration Time of Flight mass analyser.

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74. A method of mass spectrometry comprising:
providing a first electric field region;

providing a Time of Flight mass analyser comprising
an extraction or acceleration region; and

varying a first electric field applied across at
least a portion of said first electric field region such
5 that ions having substantially different mass to charge
ratios passing through said first electric field region
are accelerated and/or decelerated such that ions having
substantially different mass to charge ratios arrive at
said extraction or acceleration region at substantially
10 the same time.

75. A method as claimed in claim 74, wherein the
magnitude of said first electric field varies with time
whilst ions pass through said first electric field
15 region.

76. A method as claimed in claim 74, wherein the
magnitude of said first electric field increases with
time.

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77. A method as claimed in claim 74, wherein the
magnitude of said first electric field decreases with
time.

25 78. A method as claimed in claim 74, wherein the
magnitude of said first electric field varies
substantially sinusoidally or cosinusoidally with time.

79. A mass spectrometer comprising:
30 a fragmentation or collision cell;
a Time of Flight mass analyser comprising an
extraction or acceleration electrode and a drift or
flight region, wherein said extraction or acceleration

electrode extracts or accelerates ions in use into said drift or flight region; and

an adjustable aperture, shutter or beam stop arranged between said extraction or acceleration electrode and said drift or flight region, wherein in a mode of operation said adjustable aperture, shutter or beam stop substantially prevents or attenuates at least some ions which have been extracted or accelerated by said extraction or acceleration electrode from being transmitted into said drift or flight region.

80. A mass spectrometer as claimed in claim 79, wherein the size, area, diameter, length, width or transmission coefficient of said aperture, shutter or beam stop is adjustable.

81. A mass spectrometer as claimed in claim 79, wherein at least some parent ions are fragmented in use in said fragmentation or collision cell into fragment ions and wherein fragment ions and their corresponding parent ions exit said fragmentation or collision cell with substantially the same velocity and reach said extraction or acceleration electrode at substantially the same time.

82. A mass spectrometer as claimed in claim 79, wherein in said mode of operation multiple parent ions having different mass to charge ratios and their corresponding fragment ions are extracted or accelerated into said drift or flight region at the same time and wherein said adjustable aperture, shutter or beam stop substantially prevents or attenuates at least some parent ions and their corresponding fragment ions from being transmitted

into said drift or flight region whilst substantially permitting or transmitting at least some other parent ions and their corresponding fragment ions into said drift or flight region.

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83. A method of mass spectrometry comprising:

providing a fragmentation or collision cell, a Time of Flight mass analyser comprising an extraction or acceleration electrode and a drift or flight region, and
10 an adjustable aperture, shutter or beam stop arranged between said extraction or acceleration electrode and said drift or flight region;

extracting or accelerating ions into said drift or flight region; and

15 using said adjustable aperture, shutter or beam stop to substantially prevent or attenuate at least some ions which have been extracted or accelerated by said extraction or acceleration electrode from being transmitted into said drift or flight region.